Central Electric Power Cooperative, Inc.

Solar Water Heating Study

Final Report

January 15, 2012

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Executive Summary

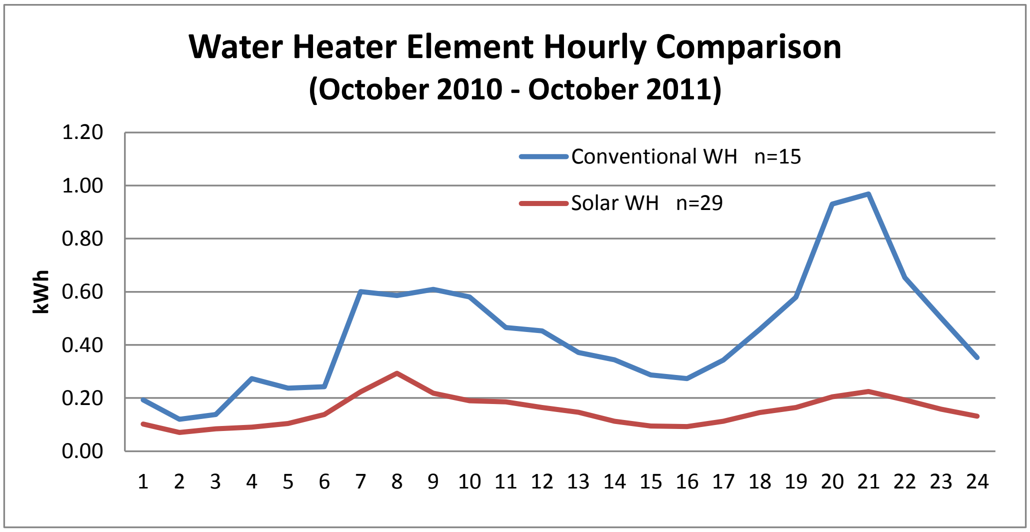
During the summer of 2010, Central Electric Power Cooperative, Inc. (CEPCI) contracted with Full Service Plumbing and Southern Energy Management to install 70 solar water heating systems across four cooperatives within their service territory. CEPCI received an American Recovery and Reinvestment Act (ARRA) grant through the South Carolina Energy Office for this project. The solar water heater systems installed were either drain-back or glycol systems. CEPCI contracted with GoodCents to monitor a sample of the solar water heaters participating in the program, determine the energy savings, and produce a final report suitable for the South Carolina Energy Office.

GoodCents installed Synergistic data loggers within the homes of 30 solar water heater participants. One data logger was installed at the customer's panel box to allow for specific end use data collection. Interval usage data was collected every 15 minutes for the premise (whole house), the air conditioning system, the heating system, the water heating system, as well as a few other loads with a dedicated circuit in the panel box. Additional 15-minute interval data for water heating specific variables was also collected, including the kWh used at the premise for water heating, the kWh delivered by the solar water heater, and the gallons of water used for water heating.

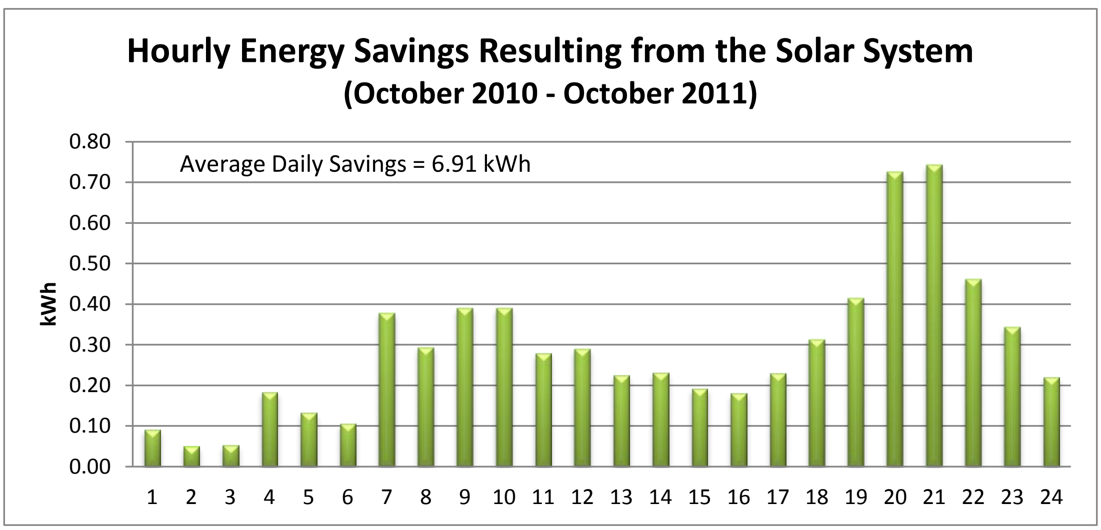
Customers were chosen for monitoring based on the location of their panel box, with unfinished basements, garages, or utility closets preferred due to the size of the data logger. Customers were also chosen based on the number of occupants within the home, which directly affected the number of solar panels installed on the home. Monitored customers were distributed proportionately by cooperative and solar system type.

Of the monitored solar systems, 15 were commissioned after three months of data collection to allow for the collection of baseline data, or conventional water heater data. The analysis included in this report compares the baseline water heater data (conventional water heater data) to that of the solar water heater system. This analysis includes one full year of data for each of the participating customers.

The following graph compares the average hourly utility supplied energy load shape of a baseline water heater (conventional water heater) and a functioning solar water heater.

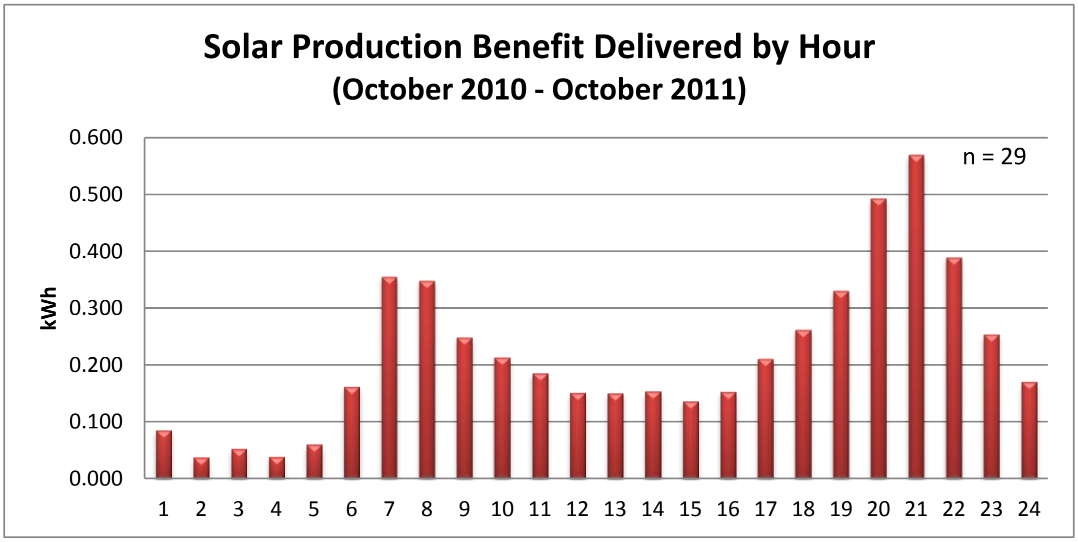


The graph above shows that the conventional water heaters use significantly more utility supplied energy than the solar water heaters. The solar water heaters are using solar energy for late evening water heater needs, rather than utility supplied energy. The graph below shows the average hourly utility supplied energy savings resulting from the installation of the solar systems.



The average daily utility supplied energy savings is 6.91 kWh. Over the course of a year, customers will save on average 2,523 kWh. The average utility electric rate over the four participating cooperatives from 2009 is 11.7 cents per kWh. This allows for a savings of $295 each year. The average cost of the glycol solar system installed was $6,445; the average cost of the drain-back solar system installed was $6,190. Including a 3% rate increase each year, the calculated payback for the solar systems ranges from 16 to 17 years. This follows the results that we have seen in other solar water heating studies.

The following graph shows the hourly solar energy benefit delivered by the solar systems.



The solar production is monitored just before the mixing valve located between the solar tank and the standard water heater tank. Therefore, the solar panel is absorbing energy all throughout the day, but we are only receiving energy readings when the customer demands or uses hot water. You can see in the graph above that the highest solar production benefit is occurring in the early morning hours and evening hours, when customers are using hot water.

The following table provides an overall summary of the analysis conducted for the solar water heater program.

Solar Water Heater Summary Table											
		Energy Consumption									
		Monthly Consumption					Daily Consumption				
Year	Month	Total	Utility Supplied		Solar Supplied		Total	Utility Supplied		Solar Supplied	
		(kWh)	(kWh)	(%)	(kWh)	(%)	(kWh)	(kWh)	(%)	(kWh)	(%)
2010	Oct	124	78	63%	46	37%	3.99	2.51	63%	1.48	37%
2010	Nov	248	153	62%	94	38%	8.26	5.11	62%	3.15	38%
2010	Dec	260	218	84%	42	16%	8.39	7.04	84%	1.36	16%
2011	Jan	284	234	83%	49	17%	9.15	7.56	83%	1.59	17%
2011	Feb	252	165	66%	87	34%	9.00	5.90	66%	3.10	34%
2011	Mar	266	157	59%	109	41%	8.60	5.08	59%	3.52	41%
2011	Apr	227	102	45%	125	55%	7.57	3.40	45%	4.16	55%
2011	May	217	86	40%	130	60%	6.99	2.78	40%	4.20	60%
2011	Jun	164	51	31%	113	69%	5.47	1.72	31%	3.75	69%
2011	Jul	160	52	33%	108	67%	5.15	1.68	33%	3.47	67%
2011	Aug	172	53	31%	119	69%	5.55	1.78	32%	3.77	68%
2011	Sep	180	67	37%	113	63%	6.01	2.16	36%	3.85	64%

Introduction

Central Electric Power Cooperative, Inc. (CEPCI) aims to have a complete understanding of solar water heating and how solar water heating system may affect their energy demand during peak and off peak hours. In the summer of 2010, CEPCI offered a solar water heating program to customers in four participating cooperatives: Berkeley, Pee Dee, Santee, and York. CEPCI contracted with Full Service Plumbing and Southern Energy Management to install 70 solar water heating systems, either drain-back or glycol systems. CEPCI received an American Recovery and Reinvestment Act (ARRA) grant through the South Carolina Energy Office for this project. CEPCI contracted with GoodCents to conduct measurement and verification (M&V) on the solar water heating program. The following report provides a detailed overview of the solar water heating program, the installation of data loggers on a sample of participants' homes, the data collected during the course of the one year-long study, and the energy savings resulting from the program.

The M&V Sample

GoodCents determined that a sample of 30 M&V customers was statistically significant for providing the energy savings resulting from the solar water heater program. Customers were chosen to participate in the M&V portion of the program based on their cooperative and the number of occupants within their home. GoodCents wanted to ensure that the entire solar water heater population was represented appropriately in the M&V sample.

The table below shows the proposed sample allocation based on cooperative and number of occupants.

Proposed Sample Allocation for CEPC Solar Water Heaters						
Distribution Cooperative	Number of SWH Installs	Baseline Allocation	Total Allocation	Breakdown by Occupancy		
				1 to 2	3 to 4	>= 5
Berkeley	5	1	2	1	1	
Pee Dee	22	5	10	5	4	1
Santee	22	5	10	4	5	1
York	21	4	8	3	4	1
Total	70	15	30	13	14	3

The baseline allocation shown in the table above is the number of sites needed to collect 2 months of baseline data prior to the installation of the solar system.

CEPCI decided to install 10 drain-back systems and 60 glycol systems. GoodCents decided accordingly to monitor 3 drain-back systems and 27 glycol systems. The following table shows the proposed allocation for the glycol systems by cooperative and the number of panels installed as part of their solar system. The number of panels installed within a system is directly related to the number of occupants within a home.

Proposed Number of SEM (Glycol) Solar Water Heater Installations by Co-op										
Distribution Cooperative	Total Number of Installs	Total Number of Baseline Installs	Total Number of Immediate Installs	Baseline Installs			Immediate Installs			
				Breakdown by # of Panels			Breakdown by # of Panels			
				1 Panel	2 Panels	3 Panels	1 Panel	2 Panels	3 Panels
Berkeley	2	1	1	1			1		
Pee Dee	10	5	5	2	2	1	2	2	1
Santee	10	5	5	2	2	1	2	2	1
York	5	3	2	1	1	1	1	1	
Total	27	14	13	6	5	3	6	5	2

Customers within each allocation bin were then chosen based on the location of their panel box within their home. Customers with unfinished garages, basements, or utility closets were preferred due to the size of the data logger. The monitoring equipment used for M&V data collection is installed at the customer's panel box.

Data Logger Installation

GoodCents installed K20 data loggers within the homes of 30 solar water heater participants. The data logger was installed at the customer's panel box to allow for specific end use data collection.

Data logger installations are performed by GoodCents technicians specifically trained for the installation of data loggers and other M&V monitoring equipment. The technician installs the data logger next to the electric utility panel. Next, the technician installs eight current transformers, or CTs, to monitor desired circuits in the panel such as each premise leg, the air conditioner, the air handler, the clothes dryer, etc.

To monitor the energy produced by the solar water heater and consumed by the home, GoodCents installed electronic metering devices, also known as energy calculators, to measure thermal energy. GoodCents used energy calculators manufactured by both Metrima and Isteq. At each installation, the solar water installer, or plumber, connects the metering devices and equipment to the solar water heater system. The plumber installed two flow meter devices to measure the gallons per minute flowing from the water heater into the customer's home. Each flow meter contains a temperature sensor. In addition to the two flow meters, with the self-contained temperature sensors, the plumber must install two additional temperature sensors. One sensor is placed in the cold water supply line coming from the street into the water heater and the other is placed on the water supply side between the water heater and the storage tank.

By calculating the difference in temperature between the sensors and using the flow rates in gallons/minute, the Metrima, or Isteq, metering device is able to calculate the amount of energy produced by the solar panels and energy consumed in the house. The Metrima and Isteq devices have an accuracy of ± 2%.

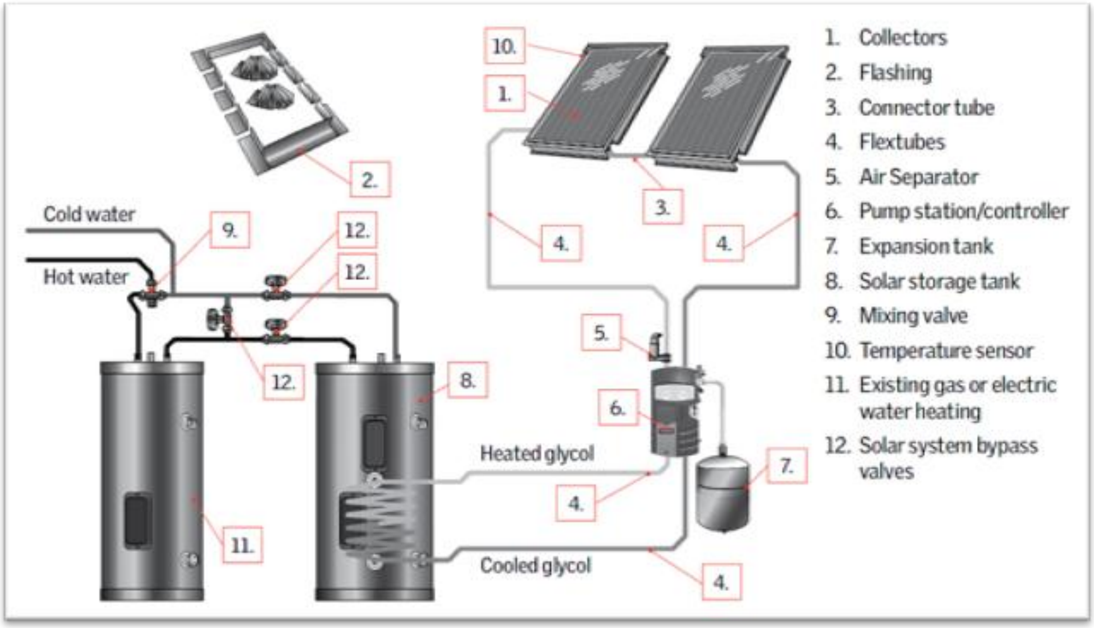
The following tables list the equipment installed at each participants home based on the solar system type.

Metering Equipment to be Installed for M&V Evaluation - Drainback Systems			
Equipment	**Number per Site**	**Location of Installation**	**Installer**
K20 Data Logger	1	Panel Box	GoodCents
Metrima Flow Meter	1	Solar Water Heater (Premise Side)	Full Service
Metrima T Weld	1	Solar Water Heater (Premise Side)	Full Service
Extra T Welds	2	Solar Water Heater (Solar Side)	Full Service
Metrima RTD	1	Solar Water Heater (Premise Side)	GoodCents
Extra RTDs	2	Solar Water Heater (Solar Side)	GoodCents

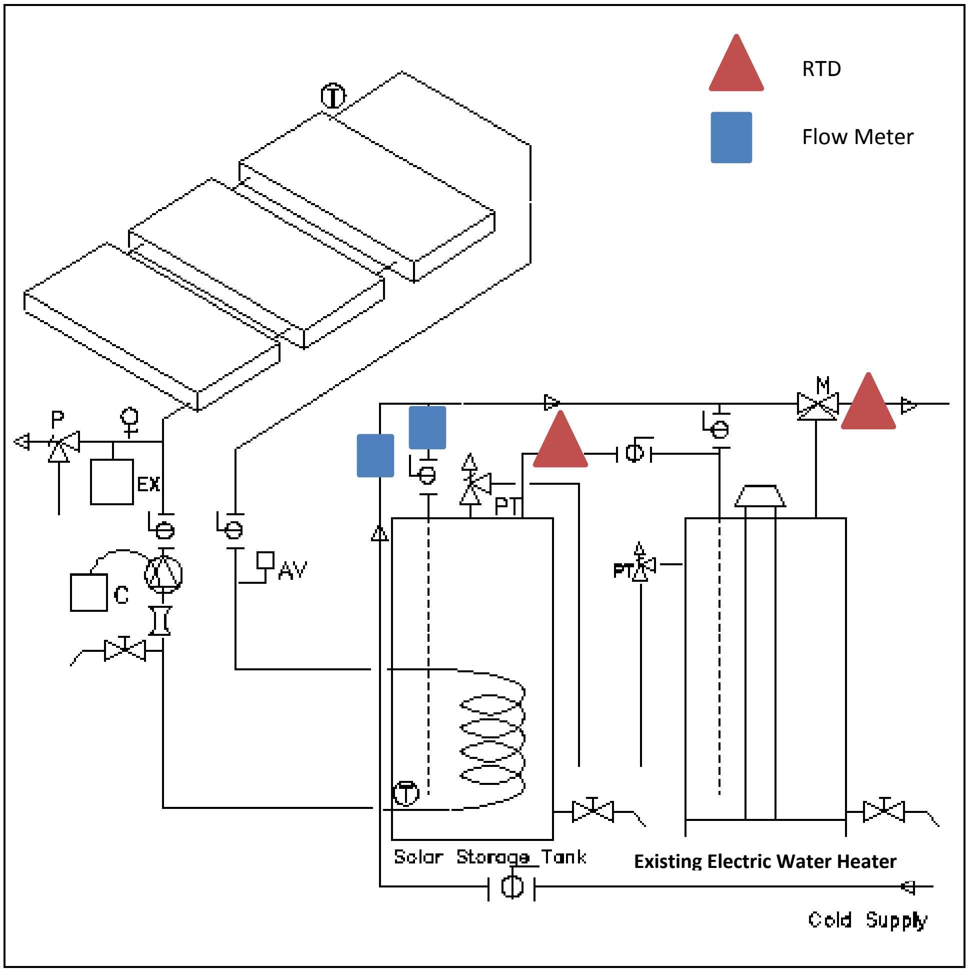
Metering Equipment to be Installed for M&V Evaluation - Glycol Systems			
Equipment	**Number per Site**	**Location of Installation**	**Installer**
K20 Data Logger	1	Panel Box	GoodCents
Metrima Flow Meter	2	Solar Water Heater (Premise Side)	SEM
Metrima T Weld	1	Solar Water Heater (Premise Side)	SEM
Metrima RTD	1	Solar Water Heater (Premise Side)	GoodCents

Last, the technician installed a wireless modem to allow for reliable communication and downloading of data from the data logger to the Load Research Engineer back at GoodCents' headquarters. The data logger records power, or kWh, with an accuracy of ± 0.4%.

The following diagram shows a glycol solar water heater installation.



The diagram below shows a glycol solar water heater installation and associated monitoring equipment.



RTD: Resistance Temperature Device

One RTD is inserted between the Solar Tank and Customer's Tank, and the other is inserted in the pipe headed into the house

Flow Meter with Metrima or Isteq Meter Calculators

Located side by side in the cold water piping before it enters the Solar Cycle to act as a baseline for **ΔT**

The diagram above shows a glycol solar water heater. The pump station is on the left, the solar storage tank is in the middle, and the existing water heater is on the right. The red triangles and squares indicate where monitoring devices were installed.

Data Collection

Interval usage data was collected every 15 minutes for the premise (whole house), the air conditioning system, the heating system, the water heating system, as well as a few other loads with a dedicated circuit in the panel box. Additional 15-minute interval data for water heating specific variables was also collected, including the kWh used at the premise for water heating, the kWh delivered by the solar water heater, and the gallons of water used for water heating. These variables are explained in the table below.

Water Heating Variables		
Variable Name	Description	Components
WH	utility supplied kWh	utility supplied kWh
Prem_kWh	kWh used at the premise level for water heating	utility and solar supplied kWh (does not include heat loss)
Prem_flow	gallons used for water heating	water flow
SWH_kWh	kWh delivered by the solar system	solar supplied kWh
SWH_flow	gallons used for water heating	water flow

The data was downloaded via wireless modem by GoodCents staff in Atlanta, Georgia. The data was then verified and analyzed using the statistical software package, SAS©.

Of the monitored solar systems, 15 were commissioned after two months of data collection to allow for the collection of baseline data, or conventional water heater data. The analysis included in this report will compare the conventional water heater data to that of the solar water heater system. This analysis includes one full year of data for each of the participating customers.

Installation Summary

The table to the right identifies the system type (glycol or drain-back), whether the site was commissioned immediately (baseline or non-baseline), the number of solar panels, and the number of occupants for each site monitored.

The baseline sites were commissioned in mid to late January or early February of 2011; therefore, their solar systems were not turned on from October 2010 until January 2011. Baseline water heaters were acting as conventional water heaters, similar to what can be found across CEPCI's service territory.

Customer 3040 has a circulation pump installed in his home. Therefore, he is expected to have more standby loss, but also benefit more from the solar system. This customer's data cannot be included in the analysis with the remaining customers and was therefore removed. This customer's data will be analyzed separately.

CEPC SWH ID Table				
Logger ID	SWH Type	Baseline	No. Panels	Occupants
1760	Glycol	Yes	2	3
1761	Glycol	Yes	1	2
1763	Glycol	No	1	2
1768	Drainback	No	2	4
1770	Glycol	Yes	2	3
1776	Glycol	No	2	3
1781	Glycol	No	2	3
1782	Glycol	Yes	1	2
1801	Drainback	Yes*	1	2
1802	Glycol	Yes	3	6
1804	Glycol	Yes	3	5
1857	Glycol	No	2	3
1858	Glycol	No	3	5
2747	Glycol	No	1	2
2769	Glycol	No	1	3
3037	Glycol	No	1	1
3040	Glycol	Yes	2	4
3045	Glycol	No	1	3
3128	Glycol	Yes	1	2
3220	Glycol	No	1	1
3226	Glycol	Yes	1	1
10233	Glycol	Yes	3	5
10272	Glycol	Yes	1	2
10301	Glycol	Yes	2	3
10306	Glycol	No	1	1
10341	Glycol	No	1	2
10344	Glycol	No	2	4
10348	Glycol	No	2	4
10350	Glycol	Yes	2	4
10355	Drainback	Yes	2	4

*Solar Pump not Functioning

Photo Library

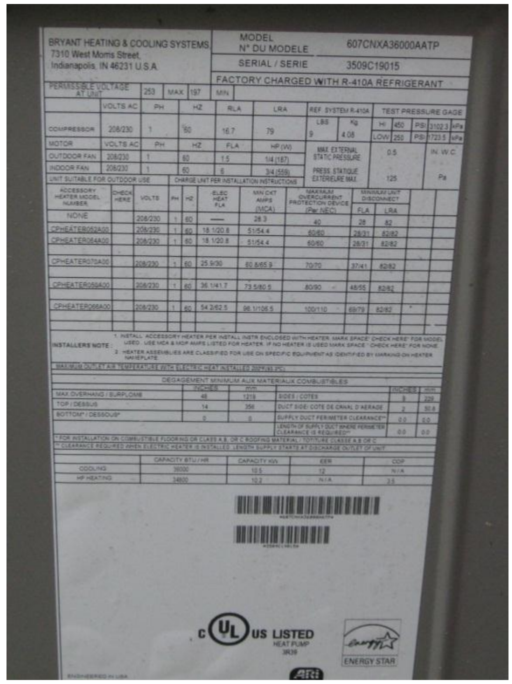
GoodCents documented each data logger installation with photos. GoodCents technicians took photos of the customer's solar water heating system, the panel box, nameplates of the air conditioner and various other end uses, as well as the data logger once installed. The following are a sample of the photos provided to CEPCI.

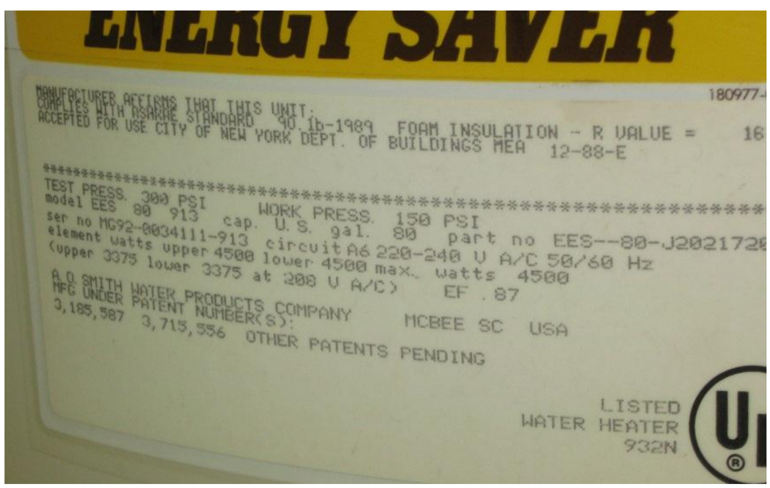
Solar Panels & Systems


VELUX

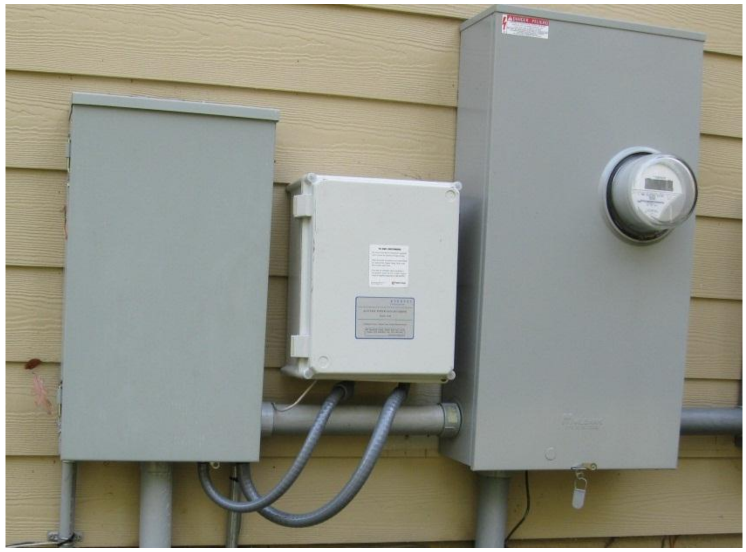

VELUX
Solar water heating
american

Name Plates


BRYANT HEATING & COOLING SYSTEMS
7310 West Morris Street,
Indianapolis, IN 46231 U.S.A.
MODEL
N° DU MODELE
607CNXA36000AATP
SERIAL / SERIE
3509C19015
FACTORY CHARGED WITH R-410A REFRIGERANT
PERMISSIBLE VOLTAGE AT UNIT
253 MAX 197 MIN
UNIT SUITABLE FOR OUTDOOR USE
CHARGE UNIT PER INSTALLATION INSTRUCTIONS
US LISTED
ENERGY STAR


ENERGY SAVER
MANUFACTURER AFFIRMS THAT THIS UNIT:
COMPLIES WITH ASHRAE STANDARD 90.1b-1989 FOAM INSULATION - R VALUE =
ACCEPTED FOR USE CITY OF NEW YORK DEPT. OF BUILDINGS MEA 12-88-E
TEST PRESS. 300 PSI WORK PRESS. 150 PSI
model EES 80 913 cap. U.S. gal. 80 part no EES--80-J202172
ser no MG92-0034111-913 circuit A6 220-240 V A/C 50/60 Hz
element watts upper 4500 lower 4500 max. watts 4500
(upper 3375 lower 3375 at 208 V A/C) EF .87
A.O. SMITH WATER PRODUCTS COMPANY MCBEE SC USA
MFG UNDER PATENT NUMBER(S):
3,185,587 3,715,556 OTHER PATENTS PENDING
LISTED
WATER HEATER
932N

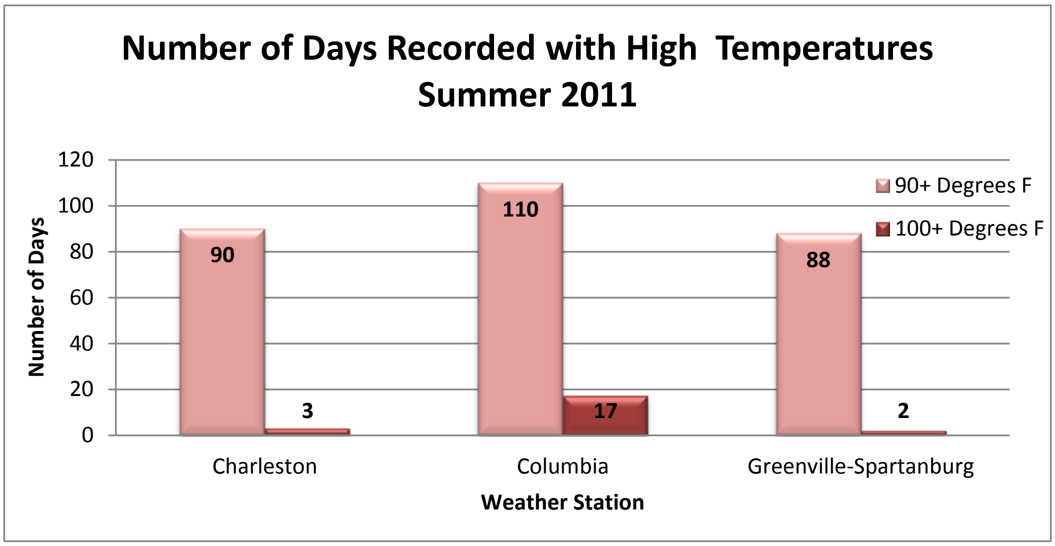
Data Loggers



Weather Review

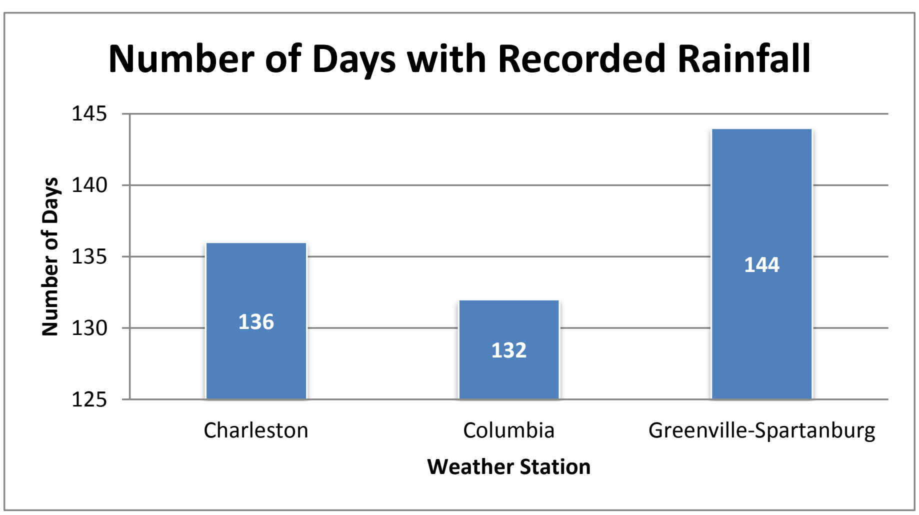
Solar water heater participants were located in three cooperatives: two in eastern South Carolina, the other in northern South Carolina. South Carolina experienced temperatures that were slightly cooler than normal in December of 2010 and January of 2011. However, South Carolina experienced a slightly warmer than normal summer in 2011.

The following graph shows the number of days between October 2010 and October 2011 with recorded temperatures higher than 90 degrees F and 100 degrees F for three weather stations in South Carolina.



Columbia, South Carolina recorded 17 days with temperatures 100 degrees F or above during the summer of 2011.

Rainfall totals recorded in the first six months of 2011 were lower than normal. However, August and September recorded higher than normal rainfall amounts. The graph below shows the number of days between October 2010 and October 2011 with recorded rainfall.

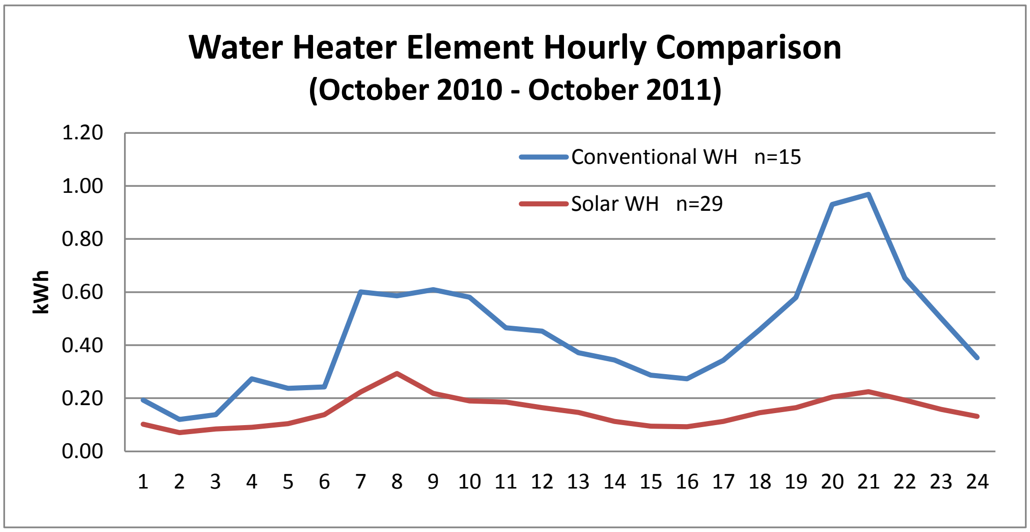


M&V Analysis

GoodCents monitored 15 water heaters for 3 months prior to the solar commissioning in order to collect baseline data, or conventional water heater data. GoodCents monitored 15 commissioned solar water heating systems for 12 months and 15 commissioned solar water heating systems for 9 months. The following section examines the characteristics of utility supplied water heating consumption, solar water heating production, the savings resulting from the solar system, demographic effects on water heating usage, and the effect of weather on the solar system.

Utility Supplied Energy Usage

The following graph compares the average hourly utility supplied energy load shape of a baseline water heater (conventional water heater) and a functioning solar water heater.



The graph above shows that the conventional water heaters use significantly more utility supplied energy than the solar water heaters. Specifically, the conventional water heaters have a peak early in the morning and again in the late evening. The solar water heaters have a small peak in the morning and a relatively flat shape in the late evening. The solar water heaters are using solar energy for late evening water heater needs, rather than utility supplied energy. Please note that the graph above and the graph below contain only 3 full months of conventional water heater data, compared to 9 months of solar water heater data.

The following tables show a summary of the monthly energy, the average demand, maximum demand, the diversified peak for conventional water heaters and solar water heaters. The table below shows the summary information mentioned above for conventional water heaters only.

Conventional Water Heater Summary Table							
Year	Month	Energy		Max Demand		Diversified Peak	
		kWh	Average Demand (kWh)	Max Hourly Demand (kW)	Average Demand as a % of Max Demand	Diversified Peak	Average Demand as a % of Diversified Peak
2010	October	197	0.26	3.14	8%	1.63	16%
2010	November	263	0.41	4.12	10%	1.93	21%
2010	December	352	0.47	4.26	11%	1.79	26%
2011	January	250	0.50	4.13	12%	2.70	18%

The following table provides summary information for the total solar water heating system (both solar and utility supplied).

Solar Water Heater Summary Table - Total kWh							
Year	Month	Energy		Max Demand		Diversified Peak	
		kWh	Average Demand (kWh)	Max Hourly Demand (kW)	Average Demand as a % of Max Demand	Diversified Peak	Average Demand as a % of Diversified Peak
2010	October	124	0.17	5.41	3%	1.15	14%
2010	November	248	0.34	4.34	8%	2.21	16%
2010	December	260	0.35	6.18	6%	1.76	20%
2011	January	284	0.38	6.24	6%	2.09	18%
2011	February	252	0.38	6.23	6%	1.63	23%
2011	March	266	0.36	6.05	6%	1.71	21%
2011	April	227	0.32	5.74	5%	1.43	22%
2011	May	217	0.29	5.26	6%	1.26	23%
2011	June	164	0.23	3.79	6%	0.85	27%
2011	July	160	0.21	3.97	5%	1.12	19%
2011	August	172	0.23	4.35	5%	0.94	25%
2011	September	180	0.25	4.46	6%	1.08	23%

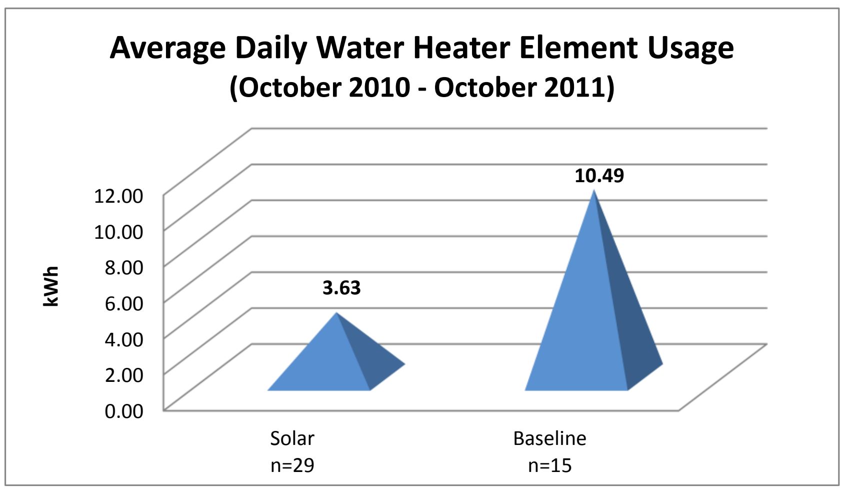
The following table provides summary information for the solar component of the solar system only.

Solar Water Heater Summary Table - Solar Component Only							
Year	Month	Energy		Max Demand		Diversified Peak	
		kWh	Average Demand (kWh)	Max Hourly Demand (kW)	Average Demand as a % of Max Demand	Diversified Peak	Average Demand as a % of Diversified Peak
2010	October	46	0.20	4.87	4%	1.09	18%
2010	November	94	0.22	3.84	6%	1.47	15%
2010	December	42	0.15	3.96	4%	1.34	11%
2011	January	49	0.16	4.27	4%	1.37	12%
2011	February	87	0.21	4.82	4%	1.32	16%
2011	March	109	0.24	4.94	5%	1.50	16%
2011	April	125	0.26	4.89	5%	1.39	18%
2011	May	130	0.26	4.54	6%	1.27	20%
2011	June	113	0.23	3.83	6%	0.93	24%
2011	July	108	0.21	3.69	6%	1.14	18%
2011	August	119	0.22	4.03	5%	1.16	19%
2011	September	113	0.22	3.99	5%	1.13	19%

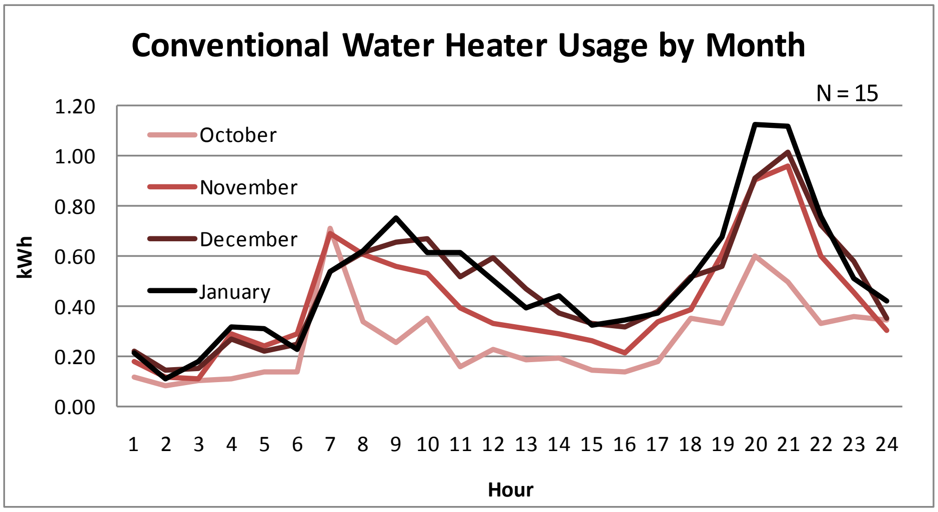
The following table provides summary information for the electric supplement portion of the solar system only.

Solar Water Heater Summary Table - Electric Supplement Only							
		Energy		Max Demand		Diversified Peak	
Year	Month	kWh	Average Demand (kWh)	Max Hourly Demand (kW)	Average Demand as a % of Max Demand	Diversified Peak	Average Demand as a % of Diversified Peak
2010	October	78	0.10	2.39	4%	0.57	18%
2010	November	132	0.21	2.16	10%	0.83	26%
2010	December	218	0.29	3.31	9%	1.01	29%
2011	January	170	0.31	3.18	10%	1.04	30%
2011	February	165	0.25	3.43	7%	0.88	28%
2011	March	157	0.21	3.10	7%	0.85	25%
2011	April	102	0.14	2.58	5%	0.75	19%
2011	May	86	0.12	2.08	6%	0.52	22%
2011	June	51	0.07	1.48	5%	0.25	28%
2011	July	52	0.07	1.26	6%	0.23	31%
2011	August	55	0.07	1.32	6%	0.28	27%
2011	September	81	0.09	2.09	4%	0.61	15%

The graph to the right shows the average utility supplied energy for the conventional water heaters and the solar water heaters on a daily basis. This graph shows that the solar water heating system is saving 6.8 kWh a day compared to the conventional water heater.

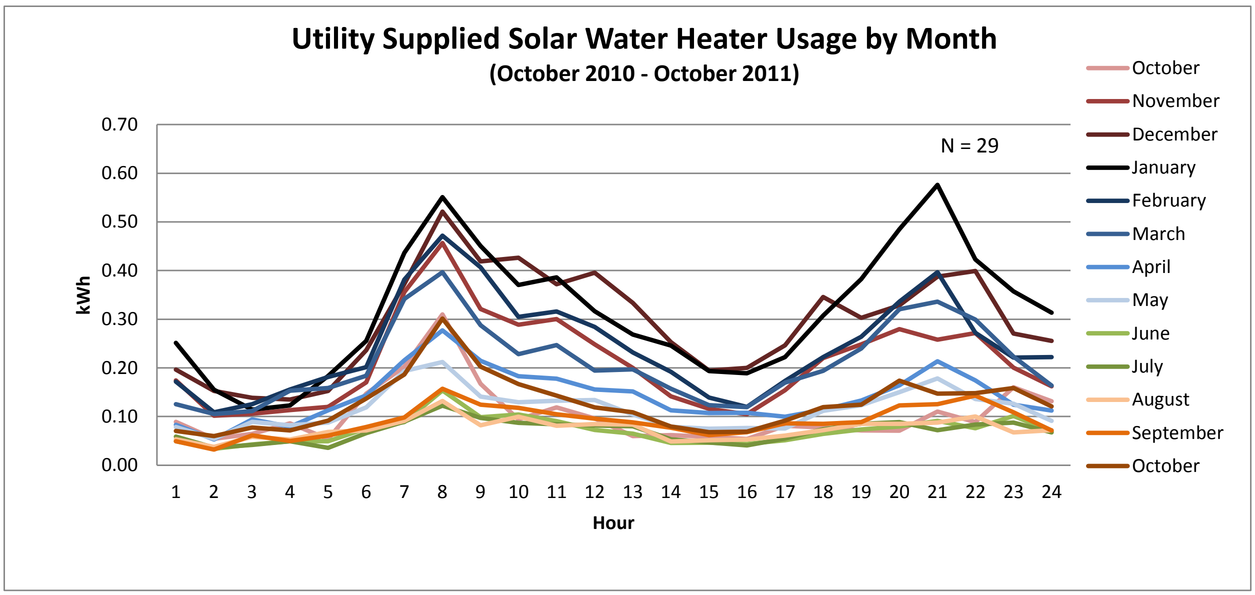


Outside temperatures can impact water heating loads. Colder inlet temperatures will cause the water heater to run longer to warm the water to the desired temperature. Customer behavior may also change as a result of outside temperature. Customers may take hotter showers in the winter and cooler showers in the summer. The following graph shows utility supplied water heater usage for the conventional water heaters by month.



The graph above shows that conventional water heater usage increases from October to January as temperatures get cooler.

The following graph shows utility supplied water heater usage for the solar water heating systems by month.



As expected with both the conventional systems and the solar systems, December, January, and February require the most utility supplied water heating usage. Summer months (May, June, and July) require very little utility supplied water heating usage for the solar water heating systems.

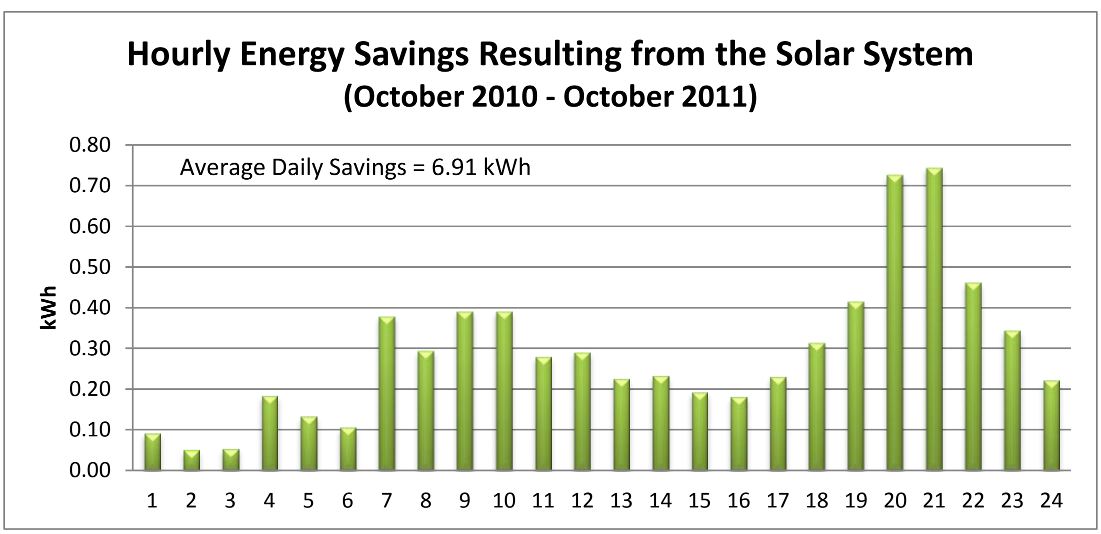
Average Utility Supplied Usage by Month			
Month	Conventional WH	Solar WH	Difference
10	94.96	33.25	61.71
11	262.54	132.21	130.32
12	351.72	218.11	133.61
1	250.32	169.91	80.40
2		164.81	
3		157.35	
4		102.07	
5		85.59	
6		51.49	
7		52.19	
8		54.91	
9		81.04	
10		89.21	

The table to the left shows the total monthly utility supplied usage for each water heating type. The table below and to the right shows the maximum utility supplied kW observed during a 15-minute interval each month (averaged over all customers) for both types of water heating systems.

Average Utility Supplied Maximum kW by Month			
Month	Conventional WH	Solar WH	Difference
10	4.45	3.90	0.54
11	4.66	4.22	0.44
12	4.92	4.37	0.55
1	4.65	4.21	0.43
2	4.71	4.28	0.44
3		4.32	
4		4.04	
5		3.53	
6		2.90	
7		3.01	
8		2.96	
9		3.82	
10		4.06	

The solar water heaters are consistently saving 0.4 to 0.5 kW on the maximum water heater demand.

The graph below shows the average hourly utility supplied energy savings resulting from the installation of the solar systems.

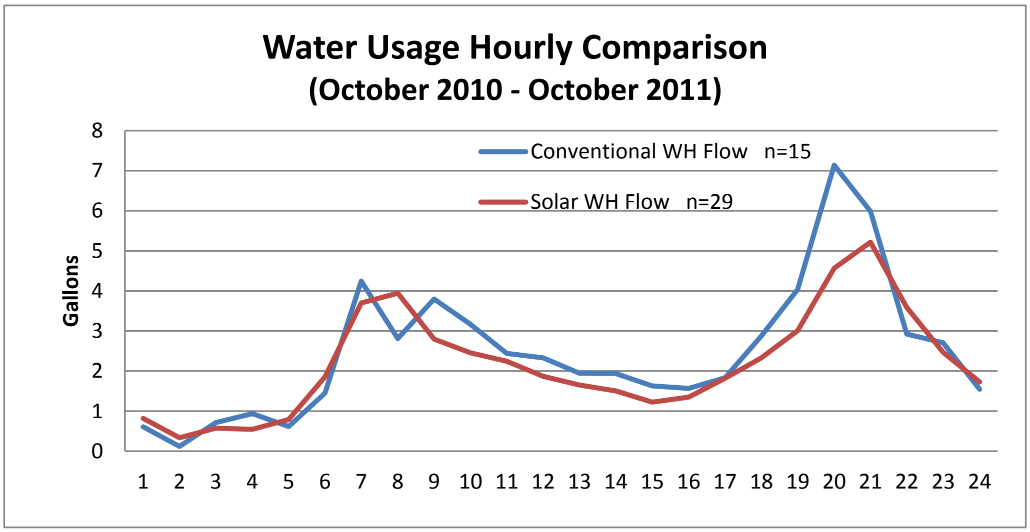


Customers are saving the most energy in the evenings at 8:00 and 9:00 pm. The average daily utility supplied energy savings is 6.91 kWh.

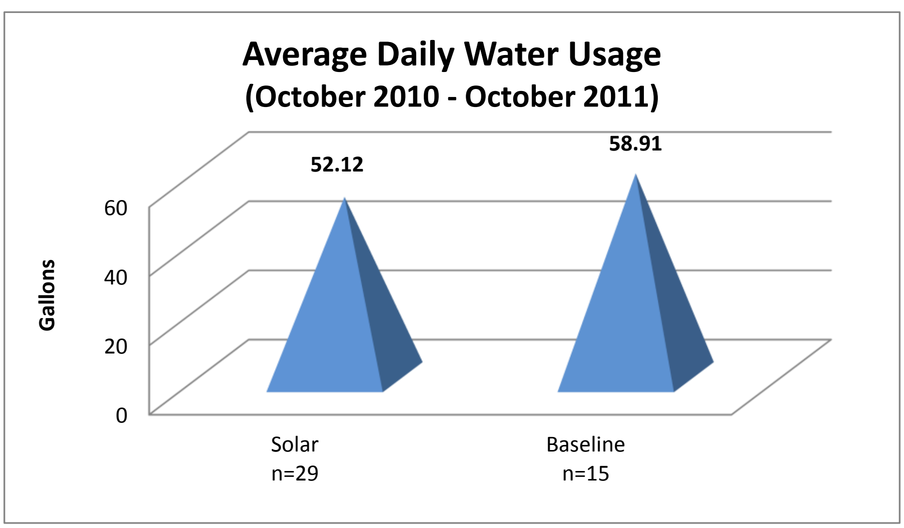
Over the course of a year, customers will save on average 2,523 kWh. The average utility usage rate over the four participating cooperatives from 2009 is 11.7 cents per kWh. This allows for a savings of $295 each year. The average cost of the glycol solar system installed was $6,445; the average cost of the drain-back solar system installed was $6,190. Including a 3% rate increase each year, the calculated payback for the solar systems ranges from 16 to 17 years. This follows the results that we have seen in other solar water heating studies.

Water Usage

The graph below shows the average hourly water usage, in gallons, for a baseline (conventional) water heater and a solar water heater customer. Again, please note that the graphs below contain only 3 full months of conventional water heater data, compared to 7 months of solar water heater data.

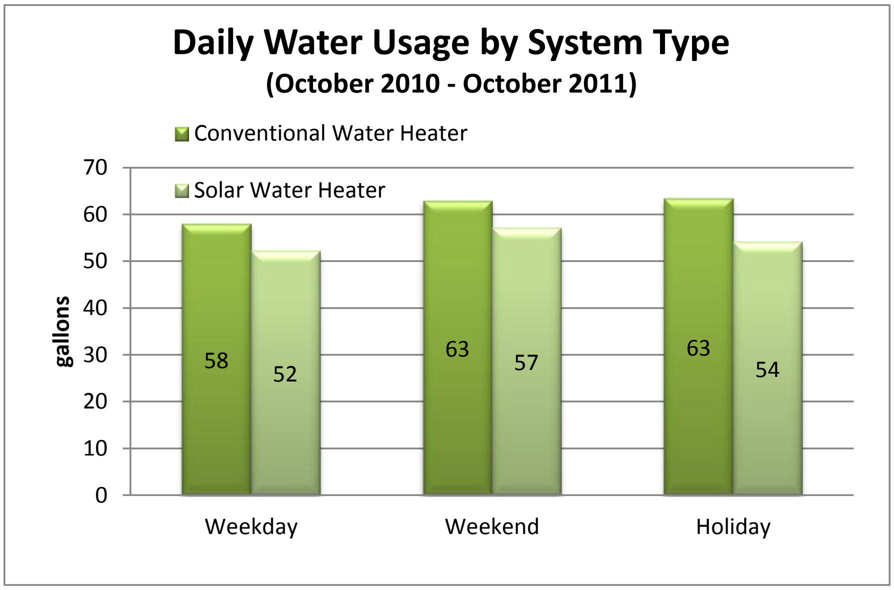


The graph to the right shows the average daily water usage for the conventional water heater and the solar water heater customers on a daily basis. The difference between the solar water heater customers and the baseline customers in this study is not significant; this difference is likely due to customer behavior within the individual samples.



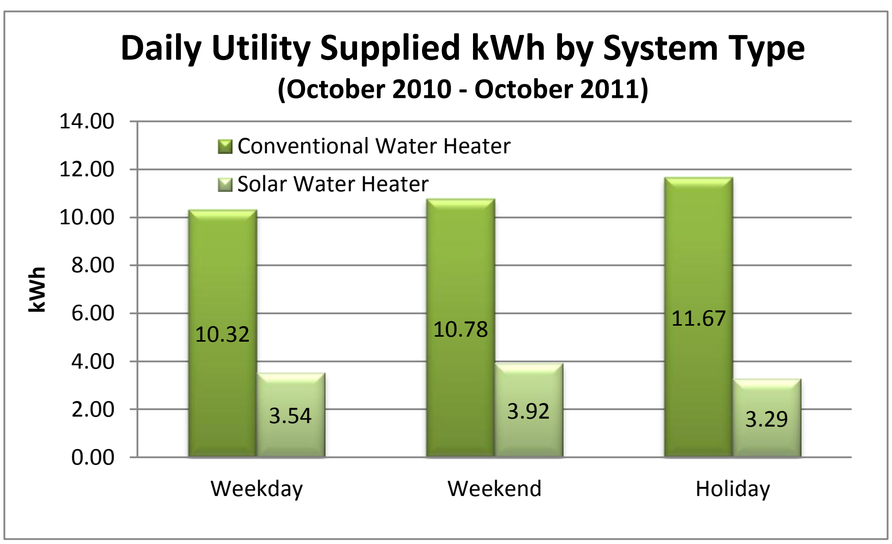
Day Type Analysis

Typically customers use more energy and water associated with water heating during holidays. The following graph shows the water usage on weekdays, weekends, and holidays.



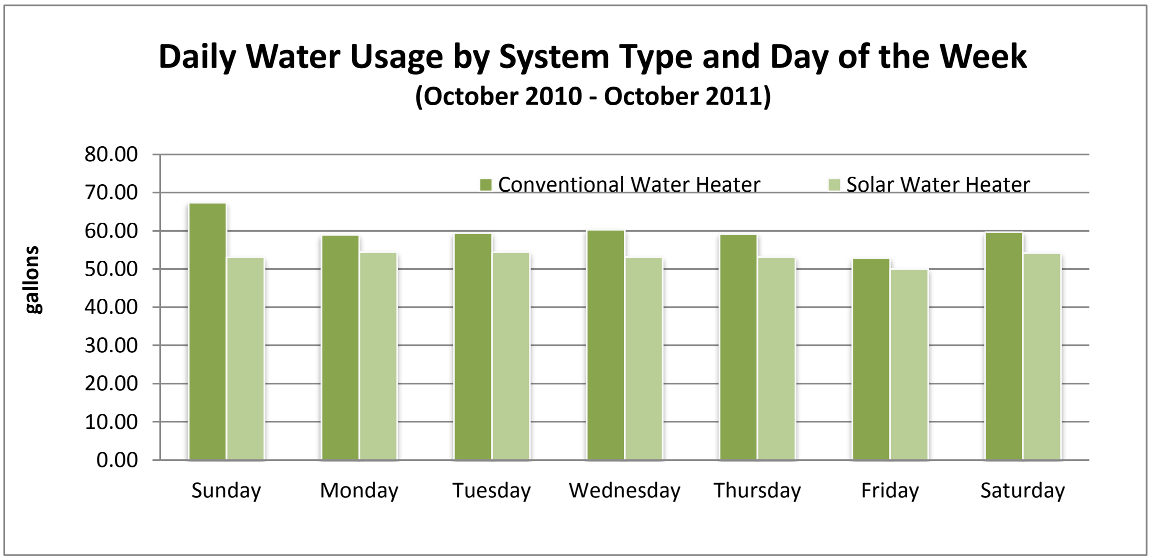
Both conventional water heater and solar water heater customers use more water on holidays and weekends than they do on weekdays. Higher water consumption on weekends and holidays is most likely due to more occupants within the home and an increase in cooking and dishwashing. Again, please note that the graphs above and below contain only 3 full months of conventional water heater data, compared to 9 months of solar water heater data.

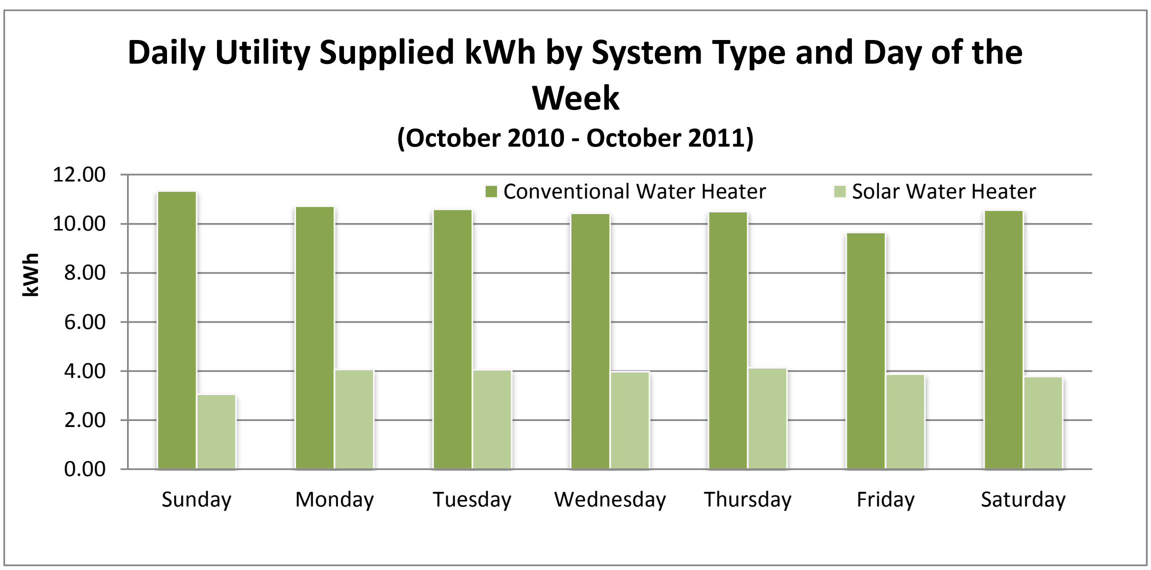
The following graph shows the utility supplied water heater usage on weekdays, weekends, and holidays.



Conventional water heater customers use slightly more energy for water heating on weekends when compared to weekdays and slightly more energy for water heating on holidays than weekends. Solar water heater customers use more energy for water heating on weekends and weekdays than they do on holidays. Compared with the water usage graph above, the solar water heater customers are using less energy on holidays and weekends even though their water usage is higher because they are benefiting from the solar system. Customers may be showering later in the day on weekends and holidays, allowing for less utility supplied energy to be used and more solar energy to be used for heating water.

The following graphs examine both the water usage and utility supplied energy usage on each day of the week.

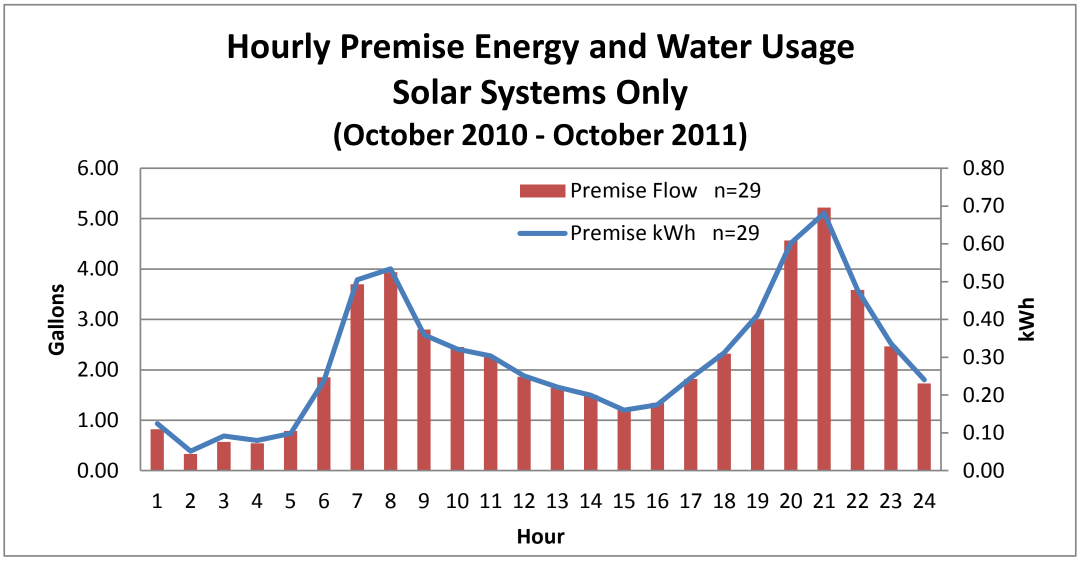




Water usage is the highest for the conventional water heater customers on Sunday; while, water usage is the highest for the solar water heater customers on Monday. Utility supplied energy is the highest on Sundays for both conventional water heater customers and solar water heater customers.

Premise Usage Analysis

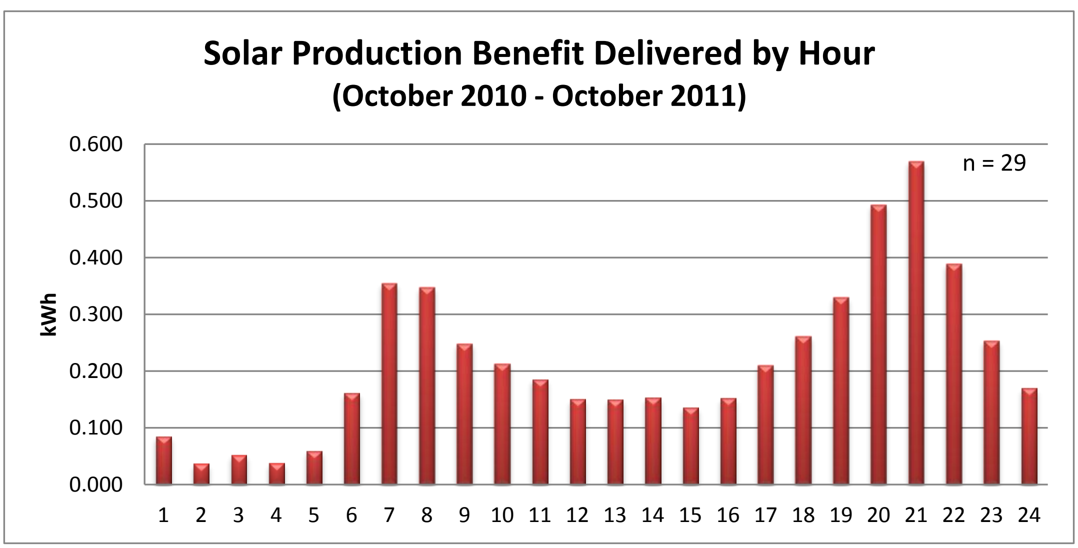
The following graph shows the average total energy used for water heating, as well as the average water flow. The total energy includes both solar and utility supplied energy, but does not include any solar or utility supplied heat that is lost over the course of the day.



You can see that the average customer has a peak water heating demand at 8:00 am, as well as 9:00 pm. The energy used directly follows the water usage.

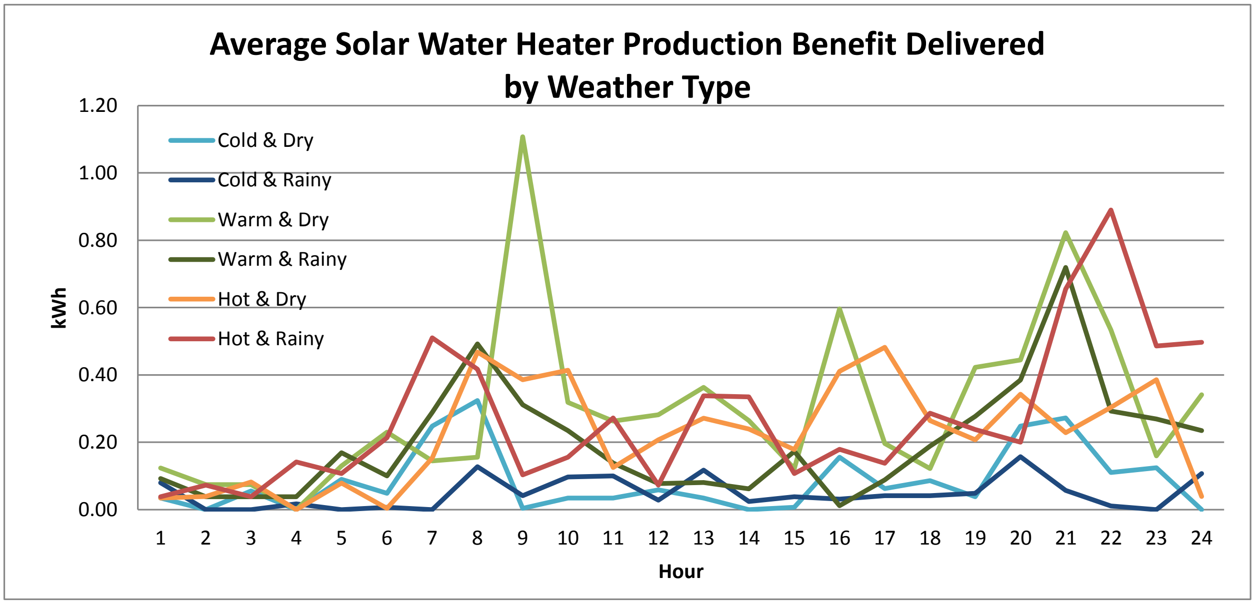
Solar Water Heater Production

The following graph shows the hourly solar energy benefit delivered by the solar systems.



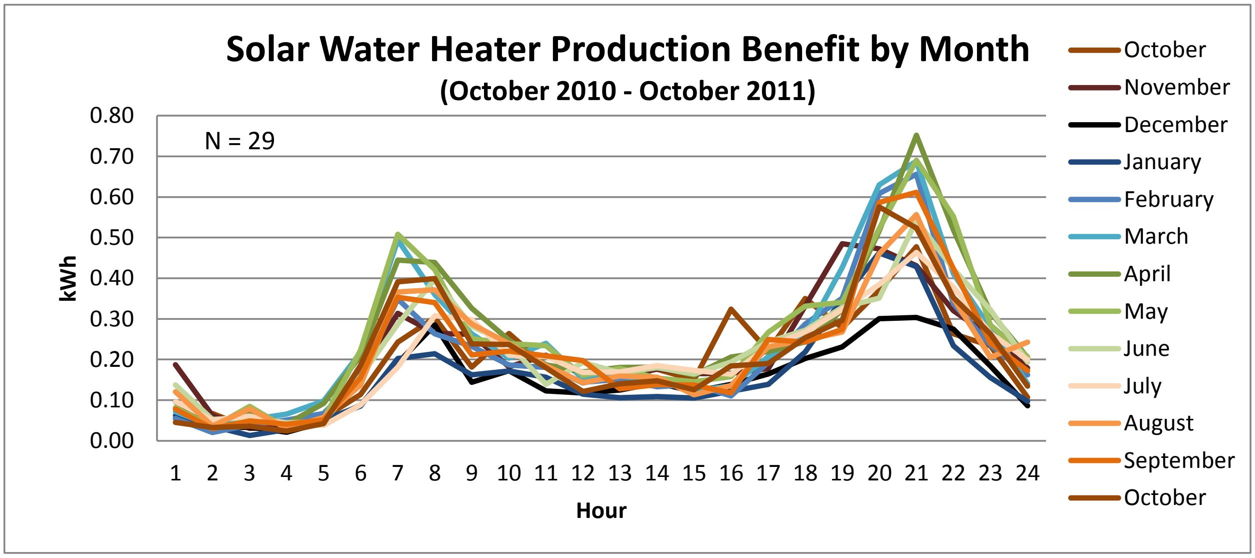
The solar production is monitored just before the mixing valve located between the solar tank and the standard water heater tank. Therefore, the solar panel is absorbing energy all throughout the day, but we are only receiving energy readings when the customer demands hot water. You can see in the graph above that the highest solar production benefit is occurring in the early morning hours and evening hours, when customers are using hot water. This is the typical load shape that we have seen for passive systems in other studies.

Solar production is dependent upon the weather. The graph below shows the solar production benefit delivered under various weather conditions.



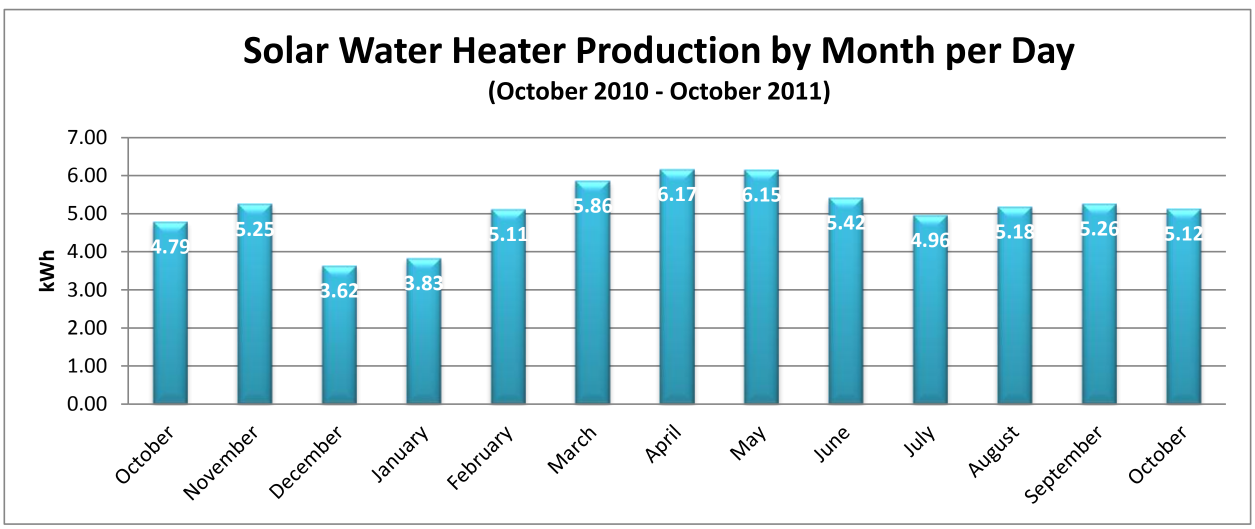
December 8th was used as the cold and dry weather day, with a high of 37 degrees F and a low of 16 degrees F. January 10th was used as the cold and rainy weather day, with a high of 36 degrees F, a low of 28 degrees F, and 0.64 inches of rainfall recorded in Columbia. April 9th was used as the warm and dry weather day, with a high of 90 degrees F and a low of 65 degrees F. April 28th was used as the warm and rainy weather day, with a high of 79 degrees F, a low of 63 degrees F, and 0.63 inches of rainfall recorded in Columbia. June 2nd was used as the hot and rainy weather day, with a high of 97 degrees F and 0.98 inches of rainfall recorded in Columbia. June 19th was used as the hot and dry weather day, with a high of 98 degrees F.

The following graph shows the average hourly solar production benefit by month.



The graph above shows that the amount of solar production delivered is increasing as the study progresses into warmer months. December has the lowest solar production delivered during the evening peak; while, March, April, May, and September have the highest solar production delivered. June, July, and August's solar production is slightly lower than that of the early summer months. This could be due to the significant amount of rainfall recorded during the latter summer months.

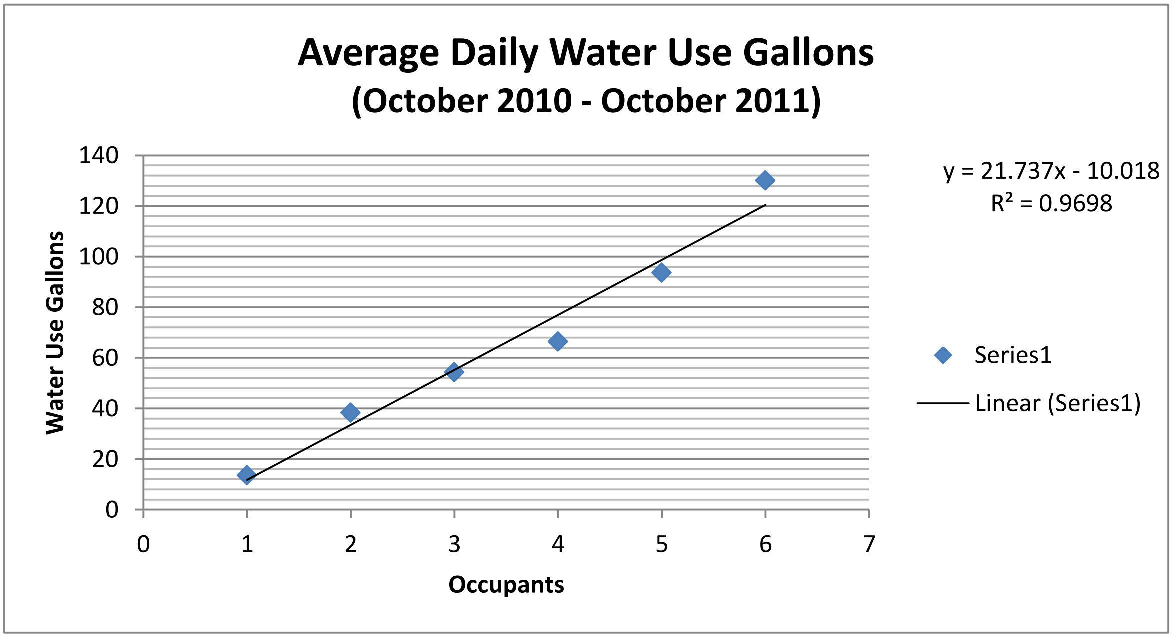
The graph below shows an average daily solar water heater production for each month in the study.

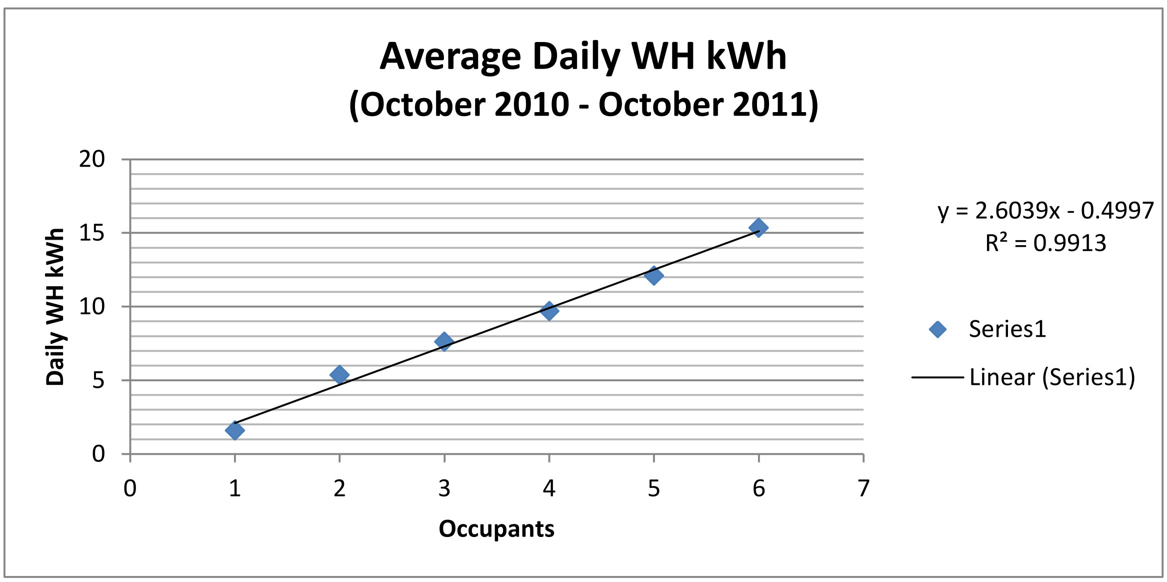


Again, December shows the lowest solar production; while April shows the highest. Overall, the daily solar production is slightly higher than what we've found in other studies.

Occupancy Analysis

Water heater usage is typically dependent upon the number of occupants within a home. The following graphs show the average daily water usage gallons and WH kWh from all sources by occupancy for all study customers except for one customer with a circulation pump.



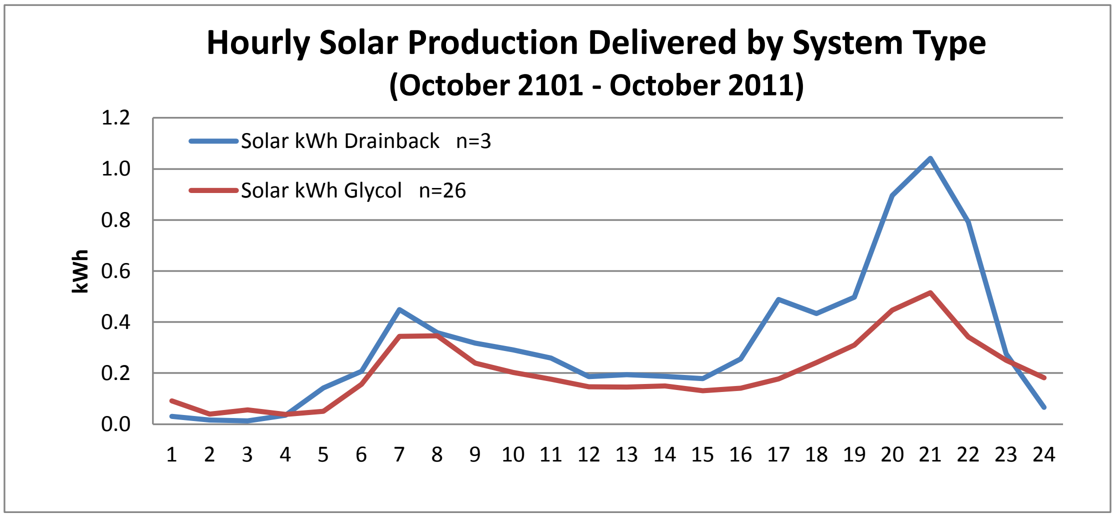


As expected, the water usage and daily kWh increases steadily for each additional occupant found within the home.

System Type Comparison

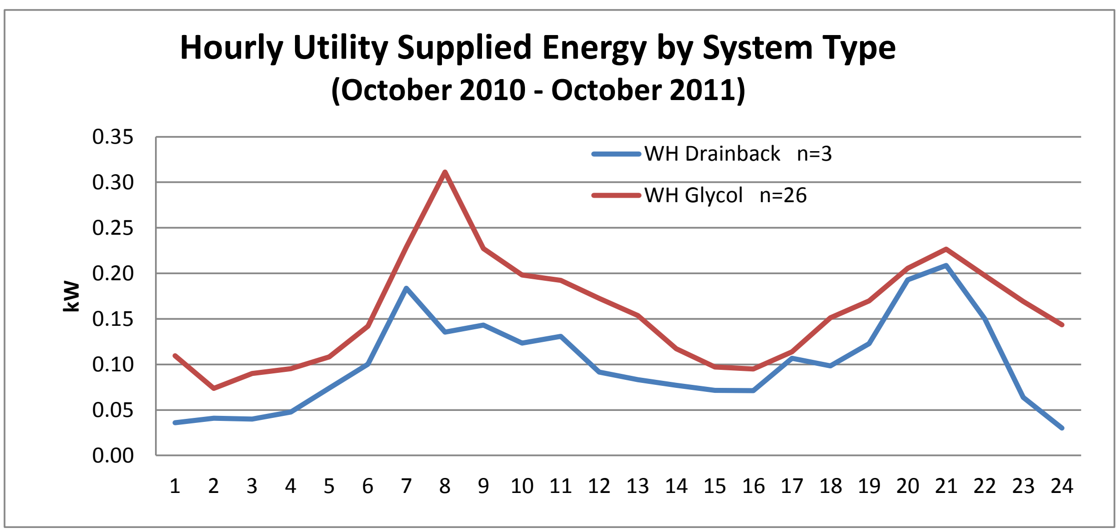
CEPCI installed two types of solar water heating systems, glycol systems and drain-back systems. The following graphs compare the two solar system types. The sample size of drain-back systems (N=3) is considerably smaller than that of the glycol systems (N=27).

The following graph shows the hourly solar energy delivered for each solar system type.

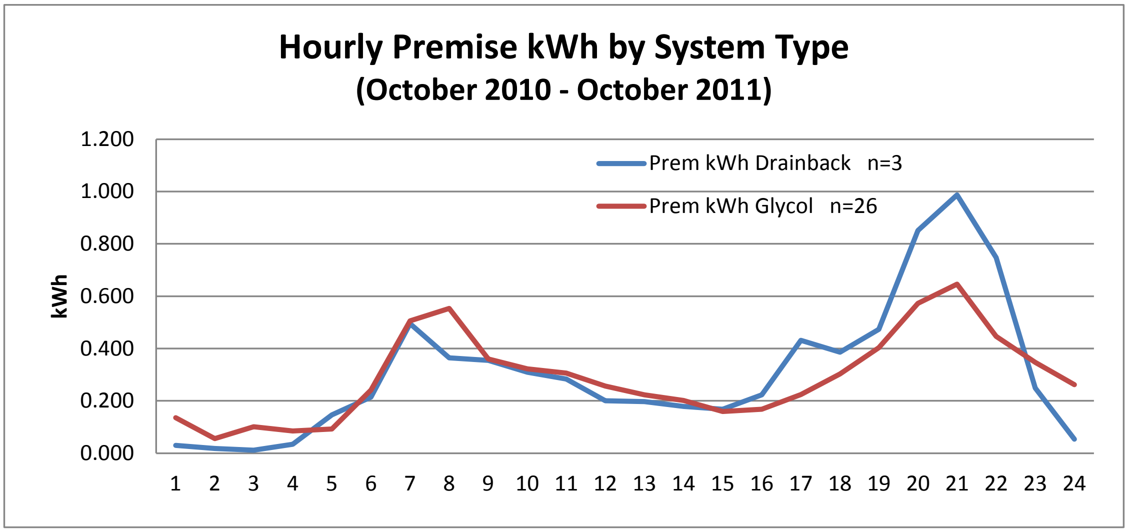


The drain-back system delivers a significantly larger amount of solar production during the evening hours when compared to the glycol systems. The difference is most likely due to customer behavior and the small sample size of drain-back systems.

The graph below shows the hourly utility supplied energy for each solar system type.



The following graph shows the total energy used for water heating for the two system types. This total energy includes both solar and utility supplied energy used by the premise.



The drain-back systems use significantly more energy in the evening; however, this is most likely due to customer behavior and the small sample size.

Conclusions

CEPCI implemented the solar water heater program in order to determine how solar systems may affect their energy demand during peak and off peak hours, to determine the level of customer acceptance of solar water heaters, and the energy savings resulting from the solar water heaters. CEPCI installed 70 solar water heating systems across four cooperatives within their service territory. GoodCents monitored 30 solar water heating systems as part of an M&V sample, in order to determine the savings resulting from the program.

The participating customers are significantly benefiting from their solar systems. Customers are able to use solar energy for late afternoon and evening water heater needs, rather than utility supplied energy. Customers are saving 6.91 kWh a day with their solar water heating system. Over the course of a year, customers will save on average 2,523 kWh, allowing for a savings of at least $295 each year. The calculated payback for the solar systems ranges from 16 to 17 years.

Both production results and savings were higher than expected, as well as higher than results GoodCents has seen at other utilities.